MOUNTAIN SITES FOR OBSERVATORIES.

By A. G. McAdie.

The establishment of the Lick Observatory marked an epoch in astrophysical work in more ways than one. The selection of a high-level site on the Pacific Coast, where it was anticipated favorable atmospheric conditions would prevail, was a recognition of the importance of conducting future research under different conditions than those experienced by the great observatories of the world — situated at low levels and near centers of population. The establishment of observatories in South America, and within the past few years the inauguration of the Solar Physics Observatory at Mt. Wilson, Cal. (elevation about 6,000 feet), are but progressive developments along the line. In brief, it is now clearly recognized that work must be carried on where there is the greatest possible freedom from the atmospheric disturbances so common at low levels. Primarily the question of definition is all important, and there is little reason to doubt that in any observatory and almost in any line of work, the greatest possible improvement will be accomplished by securing the best possible definition. Unfortunately, instruments must be located upon the ground and not in the free air. It follows therefore that the astronomer is handicapped at the very outset by the instability of the lowermost air stratum—the air close to the ground. The tremulous character of air near the ground during both day and night hours materially affects the definition. If we stop to consider the loss and gain of heat in this level, we need not be surprised at the existence of marked convectional currents and stream lines, all tending to distort the wave-front and prevent perfect definition. Where day observing is necessary, as in solar work, we have a steadily increasing instability, due to the Sun's altitude, and all the unequal warming effects, due to radiation, convection, and conduction. One anticipates therefore that the best seeing is, as a rule, during the early morning hours; or when the atmosphere is nearly quiet and there is a minimum amount of dust or haze. At night the

air near the Earth's surface is disturbed by cooling, due to radiation, and by warming, due to air motion and absorption of heat from other strata. The surface of the Earth is itself losing heat by radiation and receiving heat by slow conduction from the lower earth. Furthermore, the presence of water-vapor materially alters the heat distribution, since we have the latent heat of condensation set free during the cooling; and, conversely, a large amount of heat utilized in vaporizing water during the warming process. Nor is the radiation by gaseous matter the same as from the ground or water surfaces. In the former every particle radiates into space directly, whereas with the solid or liquid only a surface radiation occurs. Evidently then the problem is a complicated one; one in which we have to deal not only with the nocturnal cooling and diurnal warming of the Earth's surface, but also the cooling and warming of the atmosphere. Recent experiments indicate that there is at times well-marked stratification of the air and surfaces of discontinuity. This was shown to be possible by HERMANN VON HELMHOLTZ[1], in the formation of fog billows, where atmospheric strata of different density and temperature lie contiguous; and has been confirmed by recent determinations with kites and balloons. The *isothermal layer* which has just been discovered—a level at which there is a cessation of temperature distribution—is probably due to the absence of vertical convection, and is especially significant as indicating that the absorbing power of the atmosphere becomes a minimum chiefly because of the small quantity of water-vapor present at that height. To astronomers the existence of this isothermal layer is, as pointed out by Professor TURNER,[2] especially interesting in connection with atmospheric refraction. Assumptions heretofore made in connection with refraction no longer hold.

This isothermal level, however, is far beyond our reach. Its height is approximately 12,000 meters. What we are most concerned about at the present time is "good seeing," if attainable within a short distance above the ground. While what precedes shows that the full solution is not restricted to the layers of air next the ground, it has been found by LANGLEY,

[1] Paper published in 1888, Royal Prussian Academy of Sciences; translated by ABBE, Smithsonian Institution, 1891.
[2] Section A, British Association Dublin Meeting. See *Nature*, October 1, 1908, p. 550.

HALE, ABBOT, and others, that within a height of one hundred feet above the ground material improvement can be had by, (1) having the telescope as high as possible above the ground,[1] and (2) by churning the column of air in the tube of the telescope (LANGLEY and ABBOT). The result of these innovations is to thoroughly mix the air and prevent the formation of layers of different density; also, preventing any undue heating of mirrors or of tubes. To some extent "boiling" can thus be eliminated. HALE proposes to further reduce the "heating effect by doing away with the tube and using shelter houses with canvas louvres, permitting free circulation of air, but shielding from direct insolation and radiation.

From all that precedes, then, it is evident that while perfect conditions need not be expected, considerable improvement is possible in the efficiency of observatories, both in the details of work and in the increased working hours, if future observatories are located at high levels, where cloudless, dry, dust-free, haze-free, and homogeneous atmospheric conditions prevail. It is not too much to say that, except for what may be called the general routine work of an observatory, present institutions at low levels have reached the limit of their efficiency. It would be unwise to equip such observatories with the powerful instruments of modern astrophysical research. HALE puts the case fairly when he says:—[2]

"Even if the means were available for supplying the necessary instruments to existing observatories, they could not be successfully employed without atmospheric conditions much superior to those at present available."

There is one other aspect to be considered. Much astrophysical work to-day is concerned with the absorption and radiation of energy in the atmospheres of the Sun, the stars, and the planets. For example, ABBOT[3] shows that from

". . . the combined work of RUBENS, ASCHKINASS, LANGLEY, KEELER and VERY, NICHOLS (and his own) a tenth part of the average amount of water-vapor in the vertical column of atmosphere above sea-level is enough to absorb more than half of the radiation of the Earth through space, etc., and that the real surface which communicates the Earth's heat through

[1] See HALE, "Study of Conditions for Solar Research at Mt. Wilson, Cal., 1905," p. 170.
[2] "Solar Researches at Mt. Wilson," pp. 159.
[3] *Annals of the Astrophysical Observatory*, p. 172.

space is the water-vapor and carbonic acid layer lying perhaps 4,000 meters above sea-level."

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No one recognized more clearly than Professor LANGLEY the importance of good seeing.[1] No one foresaw the necessity of high-level observatories in determining the true value of the solar constant in determinations of variability of solar radiation. As early as 1881 he proved the value of experimental work at a high level on the Pacific Coast, in a region less exposed to storm and with an atmosphere immeasurably superior, so far as the absence of dust and water-vapor are concerned, to any attainable elsewhere in our country. His classic researches on Mt. Whitney and Lone Pine should be repeated at the same points for many reasons. The value of the solar constant thus redetermined would approximate 2.1 calories per square centimeter per minute, and such a determination would be authoritative.

Mt. Whitney is to-day more accessible than when Professor LANGLEY made his experiments. It is believed that there are excellent localities close by at which temporary observatories could be erected. And what is true of this section of the High Sierra holds for other mountains on the Pacific Slope. In some ways the Sierra Madre are to be preferred, owing to the general condition of air steadiness; but it may be that for purposes which do not now appear sites in the northern ranges, extending perhaps to the Cascades, would be advantageous.

While the writer does not claim any special knowledge concerning availability of different sites in the mountains of the Pacific Slope, it so happens that he has made the ascent of and measured the three highest peaks on the Pacific Coast, excluding peaks in Alaska. These are Mt. Whitney, 14,502 feet; Mt. Shasta, 14,200 feet; and Mt. Rainier, 14,394 feet.

As the various data obtained on these ascents are not readily accessible, I give the following results of our observations, and some other general information:—

MT. WHITNEY, CALIFORNIA.

This peak is situated in latitude 36° 34′ 33″ N., and longitude 118° 17′ 32″ W.

[1] *American Journal of Science*, 1903, p. 89.

References: LANGLEY, "Researches on Solar Heat"; Professional Paper No. 15, Signal Service, 1884; WHEELER, "Surveys West of the 100th Meridian, 1889"; STEWART, *Mount Whitney Club Journal,* Visalia, Cal.; LE CONTE, *Sierra Club Bulletin;* McADIE, *Sierra Club Bulletin,* June, 1904; and *Monthly Weather Review,* 1903.

The mountain can be reached in several ways; from Lone Pine on the Carson and Colorado Railroad; by trail from Kern River to Langley's Camp, 3,000 feet below the summit; and from the northern end of the Kern River. A good climber can go from Langley's Camp to the summit in less than four hours.

On September 2 to 6, 1881, Professor LANGLEY made eighteen simultaneous observations at Lone Pine and Mt. Whitney. The means of the eighteen observations for pressure and temperature are as follows:—

Lone Pine.		
Pressure	26.018 inches	$660^{mm}.9$
Temperature	$69^{\circ}.6$	$20^{\circ}.9$ C.
Mt. Whitney.		
Pressure	17.586 inches	$446^{mm}.6$
Temperature	$37^{\circ}.2$	$2^{\circ}.9$ C.

McADIE and LE CONTE obtained a mean pressure from eight readings, corrected for tempearture, scale, capillarity, and gravity, of 17.694 inches ($449^{mm}.4$) at the summit of Mt. Whitney, and mean temperature of 52° F. ($11^{\circ}.1$ C.).

Various wet-bulb readings have been obtained by LANGLEY, WHEELER, CAMPBELL, and ABBOT, all showing extreme dryness, and relative humidity varying from ten to twenty per cent.

HALLECK, with a temperature of 34° F. ($1^{\circ}.1$ C.), determined boiling-point to be $186^{\circ}.4$ F. (86° C.). HUTCHINGS reports the boiling-point at 187° F.

MT. RAINIER, WASHINGTON.

This peak is a volcanic cone, situated in latitude 46° 51′ 5″ N., and longitude 121° 45′ 28″ W.

References: BAILEY WILLIS, U. S. Geological Survey papers; *Mazama Club Bulletin,* Portland, 1905-6; *Sierra Club Bulletin,* 1905.

The mountain can be climbed from different sides, but probably the safest and easiest way is from Ashford, via Longmyers, to Paradise Valley.

On July 25, 1905, the following observations were made by A. G. McAdie and checked by Professor J. N. Le Conte:—

Mercurial barometers, Green Standard No. 1664 and No. 1554. Four readings, at Columbia Crest, summit of Mt. Rainier; mean pressure corrected for temperature, instrumental error, and gravity, 17.663 inches, $448^{mm}.6$. Mean temperature at summit, 39° F. (3°.9 C.); mean temperature of air column from readings at summit and sea-level, 50° F. (10° C.). The sea-level pressure reading, mean of Tacoma, Seattle, Portland, and Spokane, was 29.960 inches. The height, as determined by us, 14,394 feet (4,387 meters).

The boiling-point, as determined on the south rim of the crater, probably thirty meters below the true summit, was 187°.4 F. (86°.4 C.).

A sling psychrometer gave the following temperatures:—

Dry bulb,	37° F.,	36°.4,	36°.5,	36°.5,	37°.0,	mean	36°.7 F.
Wet bulb,	32	28 .0,	25 .0,	24 .2,	25 .5,	mean	26 .9

The dew-point was approximately 10°; the vapor pressure, 0.07 of an inch; relative humidity, thirteen per cent.

MT. SHASTA, CALIFORNIA.

This peak is situated in latitude 41° 24′ 28″ N., and longitude 122° 11′ 49″ W.

The following observations were made on the summit of Mt. Shasta on August 5, 1905:—

Six pressure readings. Mean pressure, corrected for temperature, instrumental error, and gravity, 17.993 inches; mean temperature of air column, 60° F.

The height, as determined by us, 14,200 feet (4,329 meters). The boiling-point at the summit, as then determined, 187°.7 F. (86°.5 C.).

In our work we fully recognize that the mean temperature of the column of air is a very uncertain quantity. The air is seldom in rest. On the dates of our ascents we noted marked stratification. Above the 10,000-foot level (3,048 meters) the drift of the air appeared to be entirely different from the motion of the lower levels.